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A DISEASE OF ALMOND TREES.

By NEWTON B. PIERCE.

(Plates XI—XIV.)

During the early part of August, 1891, while engaged in work on the vine disease of southern California, the writer observed a number of almond trees east of the village of Orange, Orange County, severely affected by a fungus infesting the leaves. This parasite is *Cercospora circumscissa*, Sacc., a form also occurring on *Prunus serotina*, the wild black cherry of the East.

The affected trees observed were large and old, but, according to Mr. Moore, the manager of the place, were unfruitful. The leaves were riddled by the fungus. Several trees had lost most of their foliage, which thickly carpeted the ground. Owing to the perforations of the parasite most of the fallen leaves looked like strainers. It seemed probable that they had fallen earlier than they would had the fungus not been present, but owing to the lack of previous observations I could not then speak positively. The observations of Mr. Ellwood Cooper given below confirm this opinion.

After these observations many others were made throughout the region. Scattered trees were seen in many orchards, and all were more or less affected. Later in August I visited Florence, Los Angeles County, and there observed the same effects, but less seriously developed. In the latter part of the same month I conversed with Mr. L. Thurston, at Santa Ana, in relation to this disease. The Thurston place has one of the most profitable almond groves of Orange County, and is near Arch Beach. At the close of September, Mr. Thurston wrote an account of the disease in his orchard, saying that the leaves remaining on the trees were seriously affected, while those already fallen, comprising most of the foliage, were completely riddled by the parasite. Mr. Ellwood Cooper, State horticultural commissioner, who has large almond interests near Santa Barbara, Cal., writes as follows respecting the disease:

The disease here has been very bad for several years; I can not recall its first appearance on my place. I have over 10,000 trees. They generally cast their leaves in June and July. The first appearance of the disease is a yellowish brown spot on the leaf. * * * Very soon the round piece falls out and the leaf falls from the tree. Sometimes there are a number of such spots in each leaf. [This is nearly always true.] It causes the leaves to fall too soon and before the woody portion has been perfected, and hence an insignificant crop the coming year. The blight does not seem to get any worse, but it is bad enough to cause great loss in crops.

It is evident that *Cercospora circumscissa*, Sacc., has developed to a very injurious extent in California, especially in the coast region. The coast counties will always be apt to suffer most from its action because of the frequent fogs and the greater general humidity of the atmosphere. Almond leaves from St. Helena, Suisun, and Acampo, Cal., fail to reveal the presence of *C. circumscissa*. Some "shot hole" fungus, however, is injurious at Suisun.

SOME OF THE STOCKS AFFECTED.

According to Mr. J. B. Ellis, *C. circumscissa* has been found on the peach in Florida by Mr. Calkins. The form affecting the almond and that on the peach, as found in California, are doubtfully distinct. Peach trees grown in close proximity to affected almond stocks may produce fruit considerably marked by this fungus. On one peach many conidia were found. There is evidence that this form does not readily mature spores on the peach, although many points of infection may be present. Thirty-six such points were seen on one stunted peach an inch in diameter. The fungus produces on the fruit a black, circular, depressed spot, which injures its appearance, although the decay does not extend inward more than one-eighth of an inch. All parts may be affected and the spots somewhat resemble those produced on the same fruit by *Cladosporium*. The leaves of peach trees are likewise considerably affected by *Cercospora*. The trees affected are only those situated so near diseased almonds that infection may occur by spores falling or blowing from them. On a portion of one peach tree thus situated the leaves near the almond were nearly destroyed. (Plate XI, Fig. 1.) Peach trees in other portions of the orchard, even those growing within 40 feet of the affected almonds, were virtually free from the disease. Leaves from peach grafts on almond stocks growing at Arch Beach showed the characteristic spots, although the conidia of *Cercospora* could not be found on the material received. These facts indicate that some immediate source of infection extraneous to the peach tree itself must be present before the tree will suffer from the disease. This is explained by the habits of the fungus on peach leaves. While these leaves obtained near affected almond stocks are often thickly infested, a single leaf sometimes showing forty or fifty characteristic points of infection, there are rarely more than two or three of these which bear conidia. They are mostly sterile on both surfaces of the leaf. The parasite penetrates and lives within the peach leaf, producing its usual effects, yet apparently fails to find the proper food supply or other conditions required for reproduction. The fact that the peach tree is usually infected from the almond is opposed to the view that the *Cercospora* found on the former is distinct from that occurring on the latter in California. Peach twigs are in rare instances infested by this fungus.

There is evidence that prune leaves are affected when the prune is grafted to almond stock. Nectarine leaves are also known to be attacked by *Cercospora circumscissa*. Leaves from two-year-old nectarine grafts on diseased almonds grown on the place of Mr. Thurston were infested.

GENERAL AND SPECIAL EFFECTS OF THE FUNGUS.

On the almond tree the effects of this parasite appear on the new and old wood, the leaves, and the nut husks. The most important direct effects are on the leaves. The indirect action of the parasite is due to this injury of the foliage. When the foliage is seriously affected it falls prematurely, leaving the new wood partially ripened or immature. Where soil conditions will admit, a new terminal growth follows the defoliation. This may be compared to the renewal of peach foliage on trees denuded by the "curl-leaf" fungus, *Taphrina deformans*, Tul., though the recovery and reclothing of the almond is less complete. Where the soil conditions are unfavorable and moisture is deficient this secondary growth does not result. On the contrary the immature terminal wood becomes more or less dried and dead. The following season many shoots may be broken with the thumb and finger. As the almond usually sheds its foliage early in the season and before the nuts have fallen, leaving the tree mostly denuded during the latter portion of the summer, any hastening of the defoliation subjects the immature wood to extremes of dryness and heat. In this respect there is a contrast between the situation of the denuded almond tree and that of the peach tree defoliated through the action of the leaf rust, *Puccinia prunispinosæ*, P. In the latter case the leaves fall late in the season, after the extremes of drought and heat are moderated and the wood is less apt to become dry. The new foliage of the almond becomes infested like the spring foliage, but it is fresher and healthier than the latter at its fall. This arises largely from the recent pushing of the growth rather than through any diminution in the virulence of the disease.

The trees and earth are covered by millions of spores capable of germinating within a few hours if placed under proper conditions of moisture. The humidity of spring is favorable to germination, while the spores are more numerous in the fall. Infested spots on the twigs are represented on Plate XI, Figs. 2 and 3. Fig. 2 is of natural size and represents new wood, while Fig. 3 is of old wood enlarged $2\frac{1}{2}$ diameters. In the former are shown nine points of infection in a little more than 2 inches. The tissue here involved is sharply defined at the margin; and this is in general characteristic. The circular portion of the cortical tissue often falls out, leaving scars or pits in or through the bark of the twig. In other cases the dead tissue clings to the twig by the center of its inner surface, while the margin has warped outward, giving the piece the form of a watch crystal attached by its convex surface. A rather exceptional case is shown in Fig. 3. This view is sufficiently

large to show the form of the affected disk with its central spore clusters. The fact of special interest here, however, is that the tissue of the branch is altered to a considerable distance from the disk of infection. This is shown by the darkened outer side of the twig. It is the under and more protected portion of the branches which becomes most thickly infested by the parasite. A branch one foot long and three-eighths of an inch in diameter bore twenty points of infection on the upper one-third, while 104 such infections were on the lower two-thirds. This condition is common, and it bears on the application of sprays for prevention. The protection from the heat of the sun on the under surface of limbs gives better conditions for germination and growth and probably accounts for the greater number of infections there.

Transverse sections show that the parasite sometimes kills the tissue of the branch as far inward as the cambium zone and xylem bundles. Figure 4 of Plate XI represents such a section magnified 16 diameters. The cortical parenchyma is mostly affected, but at the center of the affected spot the parasite has destroyed the phloem and cambium tissues, even penetrating slightly into the xylem rays. The fruiting bodies of the fungus are indicated at the margin of the section near the center of the infested spot. It can not be doubted that twigs infested in this manner at hundreds of places are much injured.

The direct action of *C. circumscissa* on the nut is of little or no importance. It can not penetrate the kernel, and it is only found on the husk, where the characteristic circular spots occur.

The leaf of the almond is the most generally attacked and most seriously affected portion of the tree. In the young and tender leaf, when viewed by transmitted light, the recently infected tissue shows a yellowish spot varying in size according to the state of advancement. This spot presents at this time a dark center. By reflected light the center appears light and the margin dark. Later the sclerotia or tubercular parts of the fungus develop, mostly within the limits of the central area, though not confined to this portion, and when the fascicles of conidia have arisen from them there is a blackish point within the light center. Viewed as an opaque object under a low power these spore clusters are of a dark olive-green color. When the conidia have arisen the infected tissue often assumes quite a dark color about its margin, which is usually well defined and nearly circular. Under the action of the parasite the affected piece soon dries sufficiently to shrink both in thickness and breadth. The shrinkage in breadth causes its rupture from the surrounding and more or less healthy tissue. It soon becomes entirely excised and falls to the ground. The opening left is bounded by partially dead and thickened tissue, and it looks as if made by fine bird shot. The entire effect resembles that produced on apricot, prune, almond, peach, and other leaves by the Australian "shot-hole" fungus, *Phyllosticta circumscissa*, Cooke. It is distinguishable, however, in most cases,

from the effects of that fungus, even to the naked eye. In many instances the openings in the almond leaf are bounded by the finer veins or vascular bundles. The midrib is rarely divided by *Cercospora*, and the larger secondary veins often prove an obstacle to its extension. In some instances cells are formed about the infested tissue of these circles apparently as a protective provision, and they are perhaps comparable to the transverse cells cutting off leaf petiole and blade when of no further use to the plant. More observations are needed to determine if this growth be common or exceptional. Where infection occurs near the margin of a leaf the opening left is semicircular, and resembles the work of the leaf cutter bee, *Megachile*. The outer effects of this fungus on the leaf are figured (Plate XI, Figs. 1, 5, 6). Figs. 5 and 6 are of the almond leaf, and represent the greater part of a leaf of natural size, with a smaller portion enlarged about 3 diameters. Fig. 1 is of a peach leaf badly infested by *Cercospora*, also natural size.

We learn through a study of the leaf tissues that all portions are involved in the effects of *Cercospora circumscissa*. The vessels are filled with a reddish, amorphous, gum-like deposit, the entire vascular bundle being involved in the discoloration. The compact upper palisade cells are shrunk and wanting in chlorophyll and amylaceous material; and this is also true for the lower, more openly arranged palisade cells or spongy parenchyma. The cell walls are yellowish, while the cell lumen usually contains a yellowish granular deposit in greater or less abundance. So far as observed, most of the chlorophyll bearing cells have their walls uninjured.

DISSEMINATION OF THE DISEASE AND PREVENTIVE MEASURES.

The small circular pieces of diseased tissue excised from the leaves of affected plants unquestionably provide for a ready spread of the disease. They bear near the center of one or both surfaces fascicles of abundant conidia. Prior to their fall from the leaf, these pieces of tissue commonly warp into the form of a watch crystal or even a cup. Moderately warped pieces are shown in cross section in Figs. 7 and 8, of Plate XI. The margin of the piece may warp either upward or downward, but in either case many fascicles of conidia are protected at the center of the concave surface from the touch of most external objects. The diameter of the cup-shaped pieces varies from 1 to 6 millimeters, and they may protect from one hundred to several hundred conidia. The spores arising from the convex surface are soon freed and scattered. Those within the concavity are retained much longer and until the pieces may be blown or carried by the water of irrigation for long distances. Unquestionably both the minute size and peculiar shape of the spore-bearing tissue greatly facilitate the dissemination of spores. Water readily separates the mature conidia from their conidiophores, and in case of a light shower they are freed and distributed over surrounding foliage in

vast numbers. Mist or fogs are not so apt to free the conidia,* but these are favorable to germination.

It is, perhaps, too early to consider preventive measures, as thus far no experiments, so far as I am aware, have been conducted to this end. There are one or two suggestions, however, which it may be well to make in view of the observations in the field and laboratory.

(1) Let all fallen foliage be gathered from beneath infested trees and burned.

(2) Have the earth beneath the infested trees carefully and completely turned under, the deeper the better.

It is important that spray applications of known fungicides should be made with thoroughness, both to trees and soil, to the latter after the fall of the foliage. In applying sprays to the tree it should be remembered that a great majority of the spores of *Cercospora circumscissa* are produced on the under surface of the leaves and branches.

OBSERVATIONS ON THE PARASITE.

The microscopical study of *Cercospora circumscissa* reveals much variation in form and habit. There are presented, by means of the camera lucida, some of the variations observed in the production and form of its conidia. There are also given numerous figures showing the characteristic but greatly varying habit of germination. (Plate XII.)

The conidia vary both in length and form. They are from 1 to 6 or 7 celled; mostly 2 to 5 celled. The distal one-fourth to one-half is usually reduced in transverse diameter and the cells are longer than those of the proximal portion. Toward the base of the conidium the cells are often somewhat distended at the equator. This gives the basal half a slightly undulating outline from septum to septum. The width of the distal end varies between $3\ \mu$ and $4\ \mu$, while the greatest breadth taken toward the base varies between $4\ \mu$ and $6\ \mu$. The basal cell contracts rather abruptly toward the end, to a transverse diameter about equal that of the distal end of the conidium. The length of the conidium is found to vary according to certain favorable or unfavorable conditions of growth. The most common variation is between $22\ \mu$

* The formation and attachment of the conidia are examined with difficulty in water. When a section bearing conidia is placed in water the spores become free. This may be avoided by placing the sections upon the slide nearly dry and afterwards moistening them gradually by breathing beneath the cover glass. The condensed vapors soon gather about the conidia and answer the purpose of a water mount in the transmission of light rays, while the conidia remain attached to their conidiophores. Glycerine or water may afterwards be run under the cover glass with much greater safety. When profile views of attached conidia are desired it is convenient to cement the back of the spore-bearing leaf tissue to a section of cork 2 millimeters in thickness. When dry the cork serves as a firm support in sectioning; and, owing to its thickness, it insures that the section shall lie so that the desired profile view is obtained. The cork is removed by running water over the sections and then teasing them with a fine brush.

and $64\ \mu$, but in many measurements I found conidia from $20\ \mu$ to $106\ \mu$ in length. One hundred measurements gave an average of $40.6\ \mu$. The conidia have a straight or variously curved form, and even bifurcate examples occur. They are often enlarged upon one side, and it is common to find their course quite angular in places. Instances are observed where projections extend out laterally much as when germinating, although these projecting cells have heavy walls like the remainder of the conidium. Not infrequently the basal cell is pyriform. The walls of the conidium, as well as the transverse septa, are mostly about $\frac{1}{2}\ \mu$ in thickness, distinct, yellowish, and firm. The cell contents are of a clear yellowish color and finely granular. When the conidium has been in water for a few hours the cell contents become more distinct, and what seem like small oil drops appear and become aggregated at or near the ends of the cell. This is the first step in the process of germination.

In germination the contents of the individual cells of the conidium press toward the ends. There appears near either end of the cell a number of small, yellowish, refractive bodies resembling oil drops. These may also be distributed through the entire cell, although most abundant at the ends. The general contents of the cells become more distinct. Through endosmose the cell soon grows turgescient, and by the pressure towards the ends the walls become distended, leaving the equator of the cell with a less diameter than the ends. This is a direct change of the condition in the cell prior to the first steps in germination. At the ends of the conidium the enlargement may become almost knob-like before any germ tube is evident. At the extremes of the cells about to develop tubes, the protoplasmic contents become fine and clear, while the cell wall at these points soon disappears, and growth begins by the pushing out of the tube or hypha. In a large number of germinating conidia observed at various times, the germ tube has nearly always arisen directly from the end of the cell or from the angle between the cell wall and septum. In comparatively few cases germination takes place directly from the side of the cell. While the cell contents are being arranged preparatory to germination the entire conidium is often seen to be passing through a new stage of development. It curves to one side in such a manner as to allow the individual cells of which it is composed to partially divide from one another. In many cases this process of division is not carried further than to allow the separating cells to assume a position at right angles to each other, thus leaving the newly separated ends of each exposed. Though only a portion of the cells become wholly separate in slide cultures, it is probable that, were the germ tubes to penetrate a natural substratum, these half divided cells would separate. It is interesting to note what advantages may arise from this strange turning to one side of the parts of the conidium. In the first place it exposes a new and tender cellulose wall at the end of the dividing cells, admitting of an easy protrusion

sion of the germ tube. It also provides that each germ tube shall be directed at an angle, often a right angle, to the direction taken by that of its fellow cell, insuring different points of infection. In case of the entire division of the cells of the conidium, still another aid to immediate dissemination is obtained. In one instance a germ tube was seen which originated from a second or inner cell, passed through the septum to the terminal cell and out at the end of the latter. (Plate XII, Fig. 23.) The germ tubes in moist cultures grow out into long mycelial hyphæ, which at an early stage appear destitute of septa, but when older the septa become distinct and often quite near together. The contents of the new hyphæ are quite clear and finely granular. The branches are not very abundant, but moderately so in some cases. They mostly arise at right angles to the parent hypha. The thickness of the parent hyphæ is well maintained through their length, although diminishing slightly to the end. There are, however, some cases where the hyphæ are enlarged or contracted at various points in their course. Conidia recently matured germinate in moist cultures very readily after a period of three or four hours; those having been matured several weeks germinate more irregularly and slowly.

The mycelium within the host plant is composed of hyphæ very similar to those of germinating spores. At points adjacent to the spore clusters the hyphæ are apt to make more or less abrupt turns, and at the angles they are sometimes considerably swollen. While culture hyphæ are rarely more than $4\ \mu$ in thickness, often considerably less, those near forming spore clusters in the leaf may reach $5\ \mu$ in thickness or even more. As the hyphæ branch and grow through the tissue of the leaf their thickness is reduced till those distant from the spore clusters are very fine. In general the hyphæ vary in thickness from 3 to $5\ \mu$. They have been seen in all the tissues of the leaf, and nearly always occupy the intercellular spaces. They are seen to wind among the cells of the palisade tissue, in some cases going directly down between those cells to the more loosely arranged palisade tissue or spongy parenchyma as the case may be. I have seen numerous hyphæ in the epidermal cells, and one hypha passed for a considerable distance, from cell to cell, through the epidermis. The finer vegetative hyphæ are quite clear and are not easily distinguished, while their septa are seen with much difficulty. The larger hyphæ are more distinctly septate and the finely granular contents are rather indistinct. The walls are distinct under an enlargement of 500 to 800 diameters.

At or near the center of the affected leaf tissue the mycelial hyphæ become grouped, either within the epidermal cells or just below them. Here is formed a tubercular mass of heavy-walled cells, giving rise to erect thick-walled hyphæ or conidiophores. The tubercular mass when soaked for several days in water may be pressed and teased apart, so as to show that it is a compound body made up of groups of thick-walled storage cells supported upon a single hypha of the mycelium. These

thick cells give rise to from 1 to 6 or more conidiophores. I have figured the tubercular mass and several of the component groups of cells with their single hyphae and varying number of conidiophores. (Plate XIII, Figs. 1-7.) The compound tubercular masses vary greatly in size, usually 3 to 15 μ in diameter. The number of conidiophores arising from them commonly varies from 20 to 50, but I have seen two well-developed conidiophores issuing alone from a stoma and having a well-defined tubercular base, with at least two distinct mycelial hyphae springing from it. It is also common to find a greater number than 50 conidiophores in one fascicle.

The fascicle of conidiophores pushes through the epidermis, or, in some cases, through a stoma. The cuticle is raised, pierced, and broken by the pressure, and the conidiophores arise to a height of 14-43 μ or more. The walls of these conidiophores are rather thick, but not as dark in color as they afterwards become. The conidiophore may be simple with the basal part somewhat swollen, or it may be more or less twisted and curved. It is common to find the distal end sharply bent to one side and then turned upward, giving a shouldered form. Where this is repeated it forms a dentate end. I have seen at least five such irregularities in one conidiophore. From the tip of this straight, curved, shouldered, or toothed conidiophore arises the conidium already described. For stages in the growth of the conidium see Plate XI, Figs. 9-17. In some cases two conidia have been seen attached to the conidiophore at the same time. One arose from the curved tip, and the other from the shoulder of the conidiophore. From the number of curves made by the conidiophore it appears probable that several successive conidia are sometimes produced upon them. In transverse diameter the conidiophore varies between 3 μ and 5 μ , but when shouldered the tip is much reduced. The fascicles may be at first made up of slightly curving and mostly tapering conidiophores. They may present a mingling of the curved, shouldered, and toothed conditions, or else, especially when old, wholly composed of the shouldered and toothed forms. The matured conidiophore is capable of sending from its extremity a secondary growth in cases where much moisture is present. This new growth takes the form of a tubular prolongation, and in some cases observed it has produced terminal conidia. In one instance two conidia were attached to this secondary prolongation. The wall of this secondary growth is lighter in color than the basal matured portion. As shown in Fig. 8, Plate XIII, these secondary growths become shouldered as with the matured basal part. They become septate, and are separated from the base by a distinct septum. The mature conidiophores may also become sparsely septate. The attachment of the conidium to the conidiophore is very unstable. In some cases there is a membrane between the mature conidium and its conidiophore, which resembles a broad and short sterigma (Plate XI, Figs. 17 and 18).

EXPLANATION OF PLATES.

PLATE XI.

- Fig. 1. Peach leaf infested by *Cercospora circumscissa*, Sacc., natural size and showing about forty-five points of infection. The circular pieces of dead tissue have fallen out in several places. The leaf was taken in October from a tree immediately adjoining a badly infested almond tree. Orchard of J. S. Baldwin, Orange, Cal.
2. Almond twig, new growth, infested by *C. circumscissa*, Sacc. From orchard of J. S. Baldwin, Orange, Cal. Natural size.
3. Almond twig, old wood (?), magnified $2\frac{1}{2}$ diameters; *a*, the oval disk of tissue killed by the fungus; *b*, central, lighter, conidia-bearing portion; *c*, the fascicles of conidiophores; *d, d*, large portion of the side of the twig, probably indirectly killed by the fungus.
4. Transverse section through an almond twig partially killed by *C. circumscissa*, Sacc., enlarged 16 times; *a*, pith cells; *b*, xylem and xylem rays; *c*, phloëm and phloëm rays; *d*, cortical parenchyma; *e*, epidermis; *f*, cortical parenchyma killed by the parasite; *g*, fruiting bodies of the parasite; *h*, cambium tissue and xylem rays destroyed.
5. Almond leaf affected by the fungus, natural size.
6. Small portion of an affected almond leaf, magnified $3\frac{1}{2}$ diameters; *a*, disk affected by the fungus; *b*, somewhat lighter, conidia-bearing center; *c*, crescent-shaped space left by the shrinking of the infected tissue; *d* and *e*, spaces where the tissue has been excised through the action of the parasite.
- 7-8. Transverse section of an affected spot in an almond leaf, showing the curvature of the tissue and the contained and protected fruiting bodies.
- 9-17. Conidia and conidiophores, the former in various stages of growth. The conidium at Fig. 17 is mature and separating from its conidiophore, showing at its base a vesicular membrane or sterigma occasionally observable. A large number of conidiophores of many forms, the straight, shouldered-curved, and more or less dentate forms are here shown.
- 18-29. Various forms of mature conidia, from those of 2 cells (Fig. 26) to those of 5 cells (Figs. 23 and 27). One bifurcate conidium is shown in Fig. 29.
30. Section of infested almond leaf, showing the fascicle of conidiophores resting on an indistinct, tubercular base, from which arise at least two hyphæ. The cells of the leaf are much shrunken and some of them are out of place, owing to the efforts made to free the mycelium from the tissue.

PLATE XII.

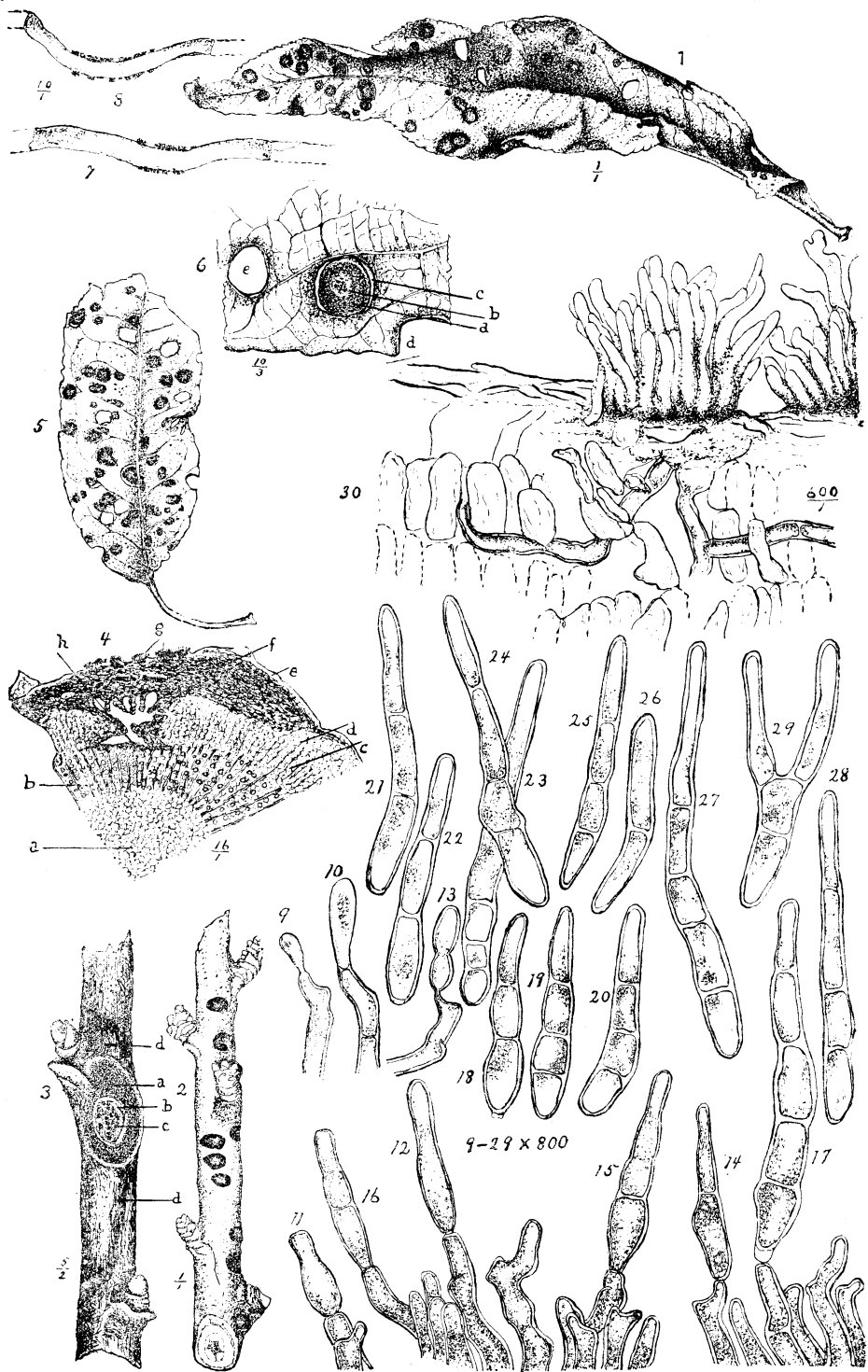
- Figs. 1-3. Conidia of *C. circumscissa* prior to germination; *a*, enlarged extremities of the spores prior to germination, and showing the clear spot seen before the pushing out of the germ tube.
4. Conidium of 4 cells with newly formed germ tubes at *a a*.
- 5-9. Conidia of 2, 4, and 5 cells, with one or more germ tubes, unbranched and of various lengths. Figs. 6-9, *a*, show the gathering of the cell contents at the ends of the cells and the numerous refractive bodies found there at the time of germination or before.
10. Conidium of 5 cells after germination from the end cells; *a*, retracted condition of the equatorial portion of the cells just prior to germination.
11. Conidium of 5 cells with 2 germ tubes; *a*, a germ tube arising from the central cell at the angle between the lateral wall and the transverse septum.

- Figs. 12. Conidium of 4 cells and 3 germ tubes; *a* and *b*, germ tubes arising directly from the side of the conidium.
13. Conidium of 3 cells and 2 germ tubes; *a*, *b*, branches arising from a germ tube near its base.
- 14–16. Three conidia previous to germination; turning in part to one side, and thus nearly separating the cells and causing them to stand at an angle to each other; *a*, *a*, *a*, points in the partly separated cells where the cell wall is not hardened and where the germ tubes usually arise.
17. Conidium of 3 cells having 2 germ tubes with its cells turned to one side, admitting of the germination of the central cell from the septum.
18. Conidium of 4 cells; *a*, 2 cells turned at right angles to the remaining 2; *c*, the outer cells of both *a* and *c* have already germinated; *d*, points where the germ tubes of the two interior cells should push out, the tube from one of these having already appeared, *b*.
19. Conidium of 3 cells and 4 germ tubes, *a*, *b*, *c*, *d*; *a*, germ tube arising from the inner end of a terminal cell.
20. A 5-celled conidium with two long, unbranched germ tubes extending at right angles to each other.
21. A conidium of 3 or 4 cells having 3 rather long, unbranched germ tubes.
22. A conidium of 3 cells and 3 germ tubes.
23. Interior germination. An inner cell has pushed out a germ tube, *a*, into and through the end cell of the conidium.
24. Conidium with several germ tubes, some septate and some branched.
- 25, 26. Conidia showing septate germ tube and branch. 25, *a*, septa; 26, *a*, branch.
27. Conidium with germ tube, showing many septa and branches. *a*, branches.
- Germinations obtained in moist cultures. All figures enlarged 800 diameters.

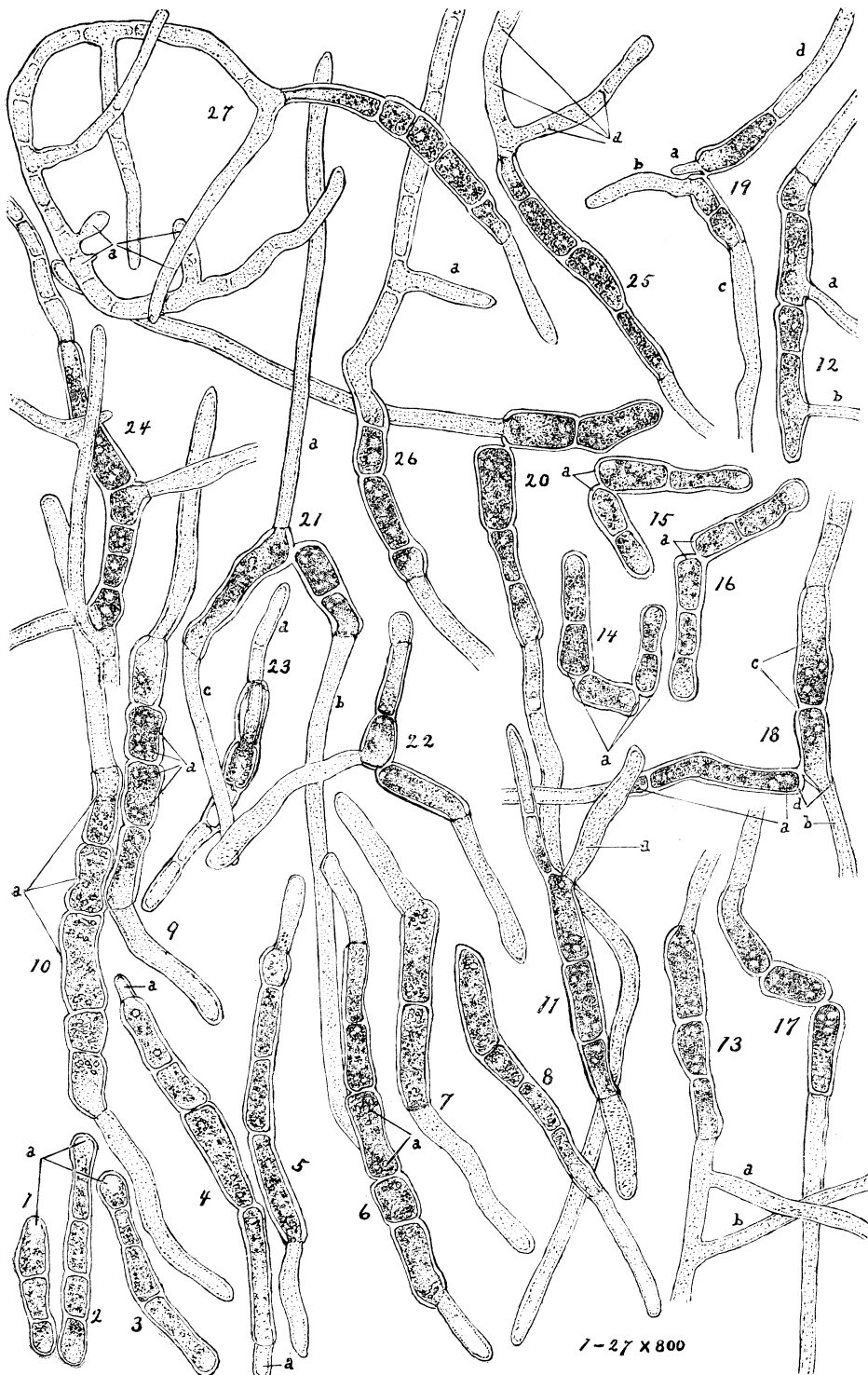
PLATE XIII.

- Fig. 1. Conidiophores of *Cercospora circumscissa*, Sacc.; *a*, tubercular mass of thick-walled cells just beneath the cuticle of the affected almond leaf, *d*, supported by the mycelium, *c*, and bearing the conidiophores, *b*.
2. Two mycelial hyphæ, *a*, *a*, connected with the thick-walled storage cells, *b*, supporting the conidiophores, *c*.
- 3–7. Various portions of the conidia-bearing organs, similar to those of Fig. 2; letters as in Fig. 2.
8. *a*, First conidiophores, with dark heavy wall; *b*, a secondary or later growth from *a*, which is shouldered, *c*, and bears at the curved tip a forming conidium, *d*; *e*, septum.
9. Secondary conidiophores, *a*, *b*, bearing conidia, *c*, *d*; *e*, *f*, points of attachment of two conidia to the single conidiophore; *f*, shouldered attachment; *e*, special attachment.
10. Fascicle of conidiophores, *a*, having thick dark walls and mostly shouldered or curved, with a secondary terminal growth, *b*. This terminal growth may or may not be septate beyond its point of origin, and is most commonly produced where there is much moisture.
11. Upper view of conidiophores.
12. An old fascicle of conidiophores, showing the twisted and distorted forms which they often take after having produced conidia.
13. Fascicle of conidiophores, *a*, with numerous attached conidia, *b*. This shows that the distal portion of the conidium is that having the reduced diameter.

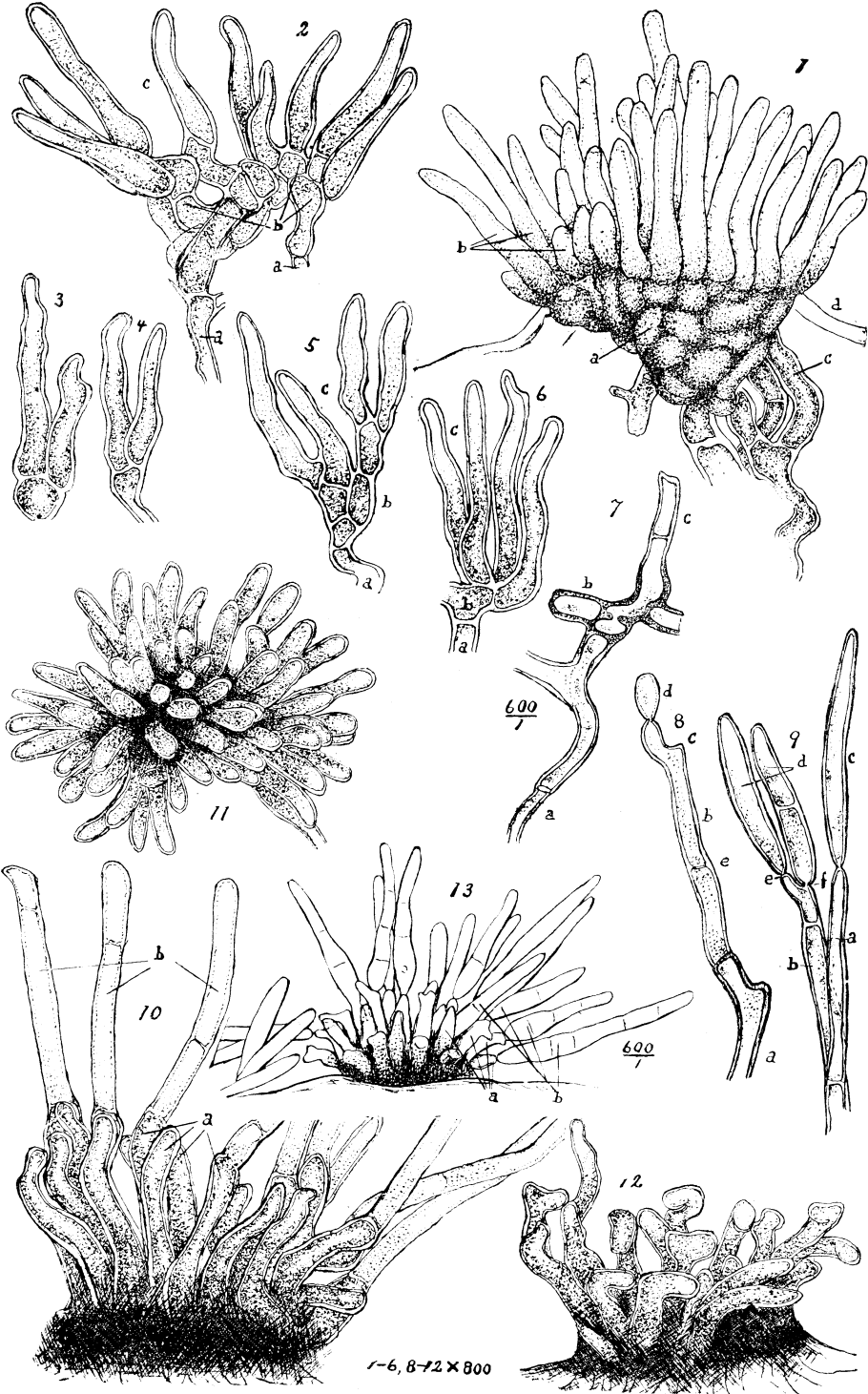
All figures from nature. Figs. 1–6 and 8–12 magnified 800 diameters; Figs. 7 and 13 magnified 600 diameters.



PIERCE ON ALMOND DISEASE.



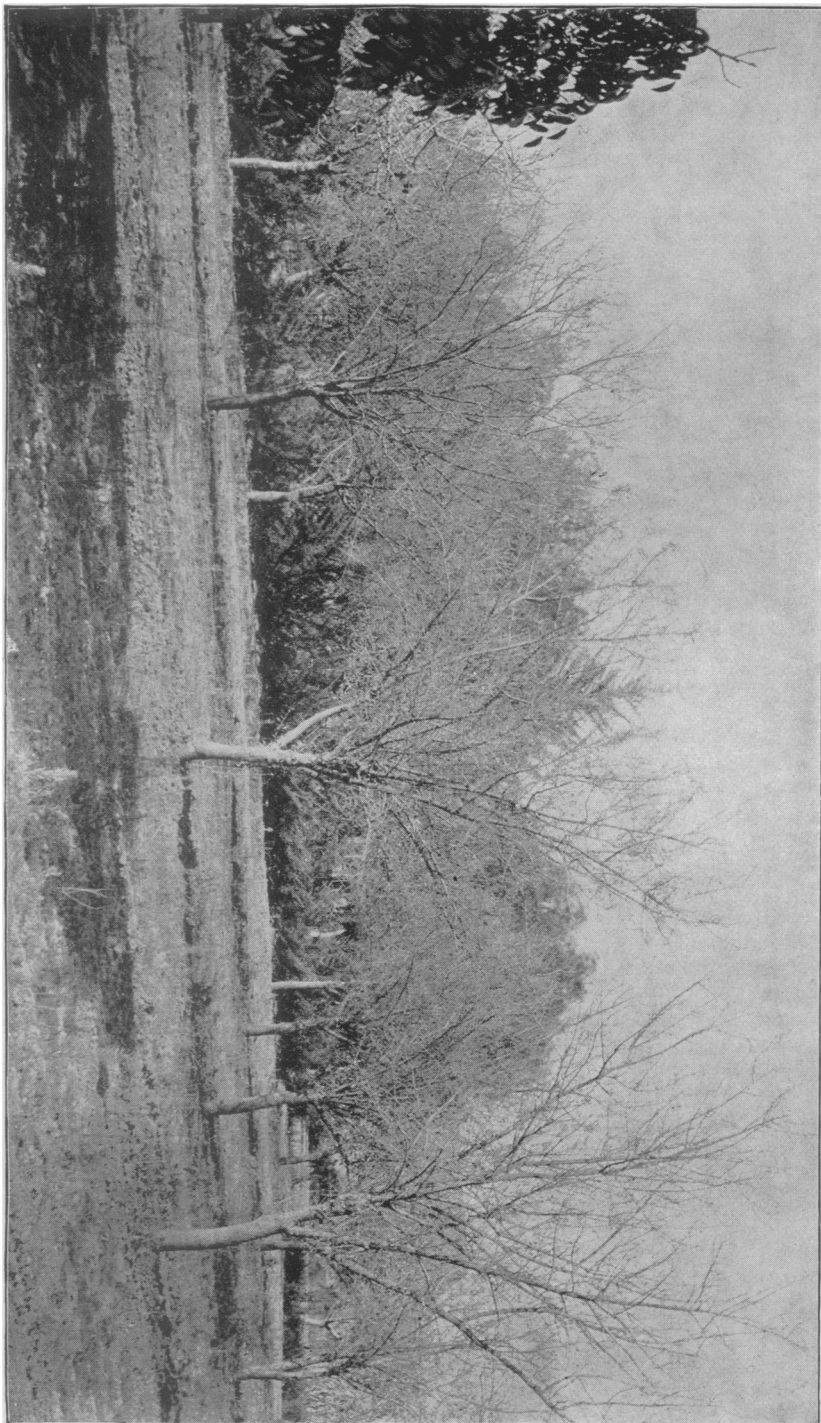
PIERCE ON ALMOND DISEASE.



1-6, 8-12 $\times 800$

N.B. Pierce

PIERCE ON ALMOND DISEASE.



ALMOND ORCHARD DEFOLIATED BY *CERCOSPORA*.

PLATE XIV.

An almond grove near Orange, Cal., prematurely stripped of leaves during July, 1891, through the action of *Cercospora circumscissa* Sacc., combined with the lack of sufficient moisture. Many terminal twigs of last year's growth are dead and dry. From photograph, August 5, 1891.

SUGGESTIONS IN REGARD TO THE TREATMENT OF *CERCOSPORA CIRCUMSCISSA*.

By B. T. GALLOWAY.

As stated by Mr. Pierce, no experiments of consequence looking toward the prevention of the disease under consideration have been made in this country. Some work, however, along this line has been undertaken in Australia, while a number of diseases of a similar nature are successfully treated every year in the eastern part of the United States. From these facts and from the life history of the fungus causing the almond disease, which Mr. Pierce has so fully set forth, we are able to make some suggestions in regard to treatment. In the first place it must be borne in mind that the foliage of the almond and peach is easily injured by both fungicides and insecticides. Bordeaux mixture, which we use successfully in combating various diseases of the pear, cherry, and quince, and which never injures the foliage of these plants, under certain conditions has been known to sometimes kill the leaves of peach trees and even in some cases to destroy young wood, fruit, and flowers. In our experience the ammoniacal solution of copper carbonate has proved the safest and best fungicide for the peach and almond. The formula we shall adopt in all our work the coming season is as follows:

Copper carbonate.....	ounces..	5
Aqua ammonia (26°)	pints..	3
Water	gallons..	45

The copper carbonate should be placed in an ordinary wooden pail and just enough water added to make a thick paste. Then pour in the ammonia and stir until all the copper is dissolved. If 3 pints of ammonia is not enough to thoroughly dissolve all the copper add a sufficient quantity to bring about this result. When completely dissolved pour the copper solution into a barrel holding 40 or 45 gallons, then fill the barrel with water. Where there are a large number of trees to treat we find it very convenient to prepare the concentrated ammoniacal solution in advance. This can be done at leisure, taking care always to put the liquid into a tightly corked jug or demijohn as soon as it is made. When ready to spray take the concentrated fluid into the field and for every three pints add 45 gallons of water.

In order to protect the foliage from the attacks of the *Cercospora* it would probably be best to begin the application of the ammoniacal so-